10/578287
IAP20 Rec'd PCT/PTO 05 MAY 2006

| Customer No. | 026418 |
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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

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| Attorney's Docket No.: | GK-OEH-237/500814.20139 | |
| U.S. Application No.: | | |
| International Application No.: | PCT/DE2004/002464 | |
| International Filing Date: | NOVEMBER 04, 2004 | 04 NOVEMBER 2004 |
| Priority Date Claimed: | NOVEMBER 07, 2003 | 07 NOVEMBER 2003 |
| Title of Invention: | INVERTIBLE LIGHT-OPTICAL MICROSCOPE | |
| Applicant(s) for (DO/EO/US): | Thomas Bocher, Hans Tandler, Hubert Wahl, Hans Brinkmann, Reiner Mitzkus, Franz Muchel, Harald Schadwinkel and Peter Gretscher | |

# VERIFIED ENGLISH TRANSLATION OF PUBLICATION NO. WO 2005/045501

## Published on May 19, 2005

UNITED STATES PATENT AND TRADEMARK OFFICE ANNEX U.S. 111

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Date March 23, 2006

Full name of the translator Daniel Cooper

Signature of the translator Daniel Cooper

Post Office Address 1310 Felicity Street, New Orleans, LA 70130

INVERTIBLE LIGHT-OPTICAL MICROSCOPE

[0001] The invention is directed to an optical microscope that can be converted by the user quickly and by a few movements of the hand for use as an upright microscope or as an inverted microscope. A microscope of this kind is known from the Laid Open Application DE 30 37 556 A1.

[0002] Already in 1887, a patent was applied for in the U.S.A. for presumably the first invertible microscope and was published as Patent No. 373,634. As can be seen clearly from Fig. 1 of this patent, an arm B is supported at a stand A so as to pivot around a horizontally extending axis of rotation. An illumination unit comprising a mirror M and optics arranged in front, a microscope stage I, and an imaging unit comprising an objective j and a tube F are mounted indirectly at the arm B at a fixed distance from one another.

[0003] In order to use the inverted variant of the microscope (indicated by solid lines), a deflecting prism is located in the imaging beam path between the tube and the objective. The arm is in a position in which the illumination unit is arranged above the object stage and the objective is arranged below the object stage.

[0004] To convert to the upright variant the arm is pivoted by 180°, the deflecting prism is removed, and the tube is fastened in the extended objective axis. The object stage which is fastened to the arm by a plug-in connection is rotated and fastened again to the arm in the same position.

[0005] DE 30 37 556 likewise discloses an optical microscope which can be used either as an upright microscope or as an inverted microscope. An imaging system and an illumination system are accommodated in a housing with external guide elements. The enclosed systems are inserted into a base frame at a defined distance one above the other by means of the guide elements. The imaging system is located above the illumination system for the upright variant and below the illumination system for the inverted variant. Different illumination systems and imaging systems can be associated with one another. However, in this case, they produce a microscope with transmitted illumination, as is also disclosed in US 373,634.

[0006] Invertible microscopes working with both vertical illumination and transmitted illumination are not known from the prior art.

[0007] Non-invertible microscopes, that is, either upright microscopes or inverted microscopes, that work with reflected light as well as transmitted light are known, for example, from US 4,210,384. As in the solutions already mentioned above, an illumination unit is arranged opposite to and in line with the objective for vertical illumination. Their required distance relative to one another and relative to an object stage located therebetween is determined by the parameters of the optical systems and is selected in such a way that the object plane is illuminated in an optimal manner and the object is sharply imaged. The illumination system and the imaging system form two mechanically separate assemblies so that the observation beam path and the illumination beam path extend spatially separate from one another.

[0008] To work with transmitted light, the illumination beam path and the imaging beam path are brought together, i.e., some optical elements are used in common by both beam paths. In so doing, either the illumination beam path is coupled into the observation beam path by an optically semitransparent deflecting element or, as in US 4,210, 384, the observation beam path is coupled into the illumination beam path. The microscope disclosed in this reference cannot be converted to an inverted microscope.

[0009] It is the object of the invention to provide an invertible optical microscope which can work as an upright microscope and alternately as an inverted microscope with reflected light and transmitted light. The resulting four microscope variants, namely, an upright variant with reflected light, an upright variant with transmitted light, an inverted variant with reflected light, and an inverted variant with transmitted light, can be assembled by the user with a few movements of the hand and without adjustment. In an advantageous manner, all components are used for each variant.

[0010] The above-stated object is met, according to the invention, by the features of claim 1. Advantageous embodiments are indicated in the subclaims.

[0011] The essence of the invention consists in particular in that the optical components for implementing an upright variant or an inverted variant with vertical illumination or transmitted illumination are accommodated in components which can be separated from one another mechanically. The interfaces of the components are situated in the infinite beam path and lie between two optically imaging elements so that by altering the arrangement of the components relative to one another in a simple manner and adding or omitting components

the user is able to change the geometric path length and the course of the imaging beam path and illumination beam path in order to operate the microscope alternately as an upright microscope or as an inverted microscope with transmitted illumination or vertical illumination.

[0012] Some embodiment examples of the invention are described in more detail in the following with reference to drawings.

[0013] Fig. 1a is a schematic diagram of the upright variant of a first embodiment example with a tube in back;

[0014] Fig. 1b is a schematic diagram of the inverted variant of the embodiment example according to Fig. 1a;

[0015] Fig. 2a is a schematic diagram of the upright variant of a second embodiment example with the tube in front;

[0016] Fig. 2b is a schematic diagram of the inverted variant of the embodiment example according to Fig. 2a;

[0017] Fig. 3a is a schematic diagram of the upright variant of a third embodiment example with the tube in front;

[0018] Fig. 3b is a schematic diagram of the inverted variant of the embodiment example according to Fig. 3a;

[0019] Fig. 4a is a schematic diagram of the upright variant of a fourth embodiment example with an L-shaped stand;

[0020] Fig. 4b is a schematic diagram of the inverted variant of the embodiment example according to Fig. 4a;

[0021] Fig. 5a is a schematic diagram of the upright variant of a fifth embodiment example with a reversible stand;

[0022] Fig. 5b is a schematic diagram of the inverted variant of the embodiment example according to Fig. 5a.

[0023] Figs. 1a and 1b show a first embodiment example for an optical microscope according to the invention. It substantially comprises the following components: stand 1, objective module 2, illumination module 3, object stage carrier 4, lamp 5, and tube 6. The

combination of components shown in Fig. 1a gives the upright variant of a first embodiment example using transmitted illumination. Fig. 1b shows the inverted variant with vertical illumination.

[0024] The stand 1 is hollow and C-shaped. One of the sides of the 'C' (the bottom side) forms the stand base 13. The two (bottom and top) sides have rectangular recesses at their free ends facing one another. A top imaging interface S1, a top illumination interface S4, a bottom imaging interface S2, and a bottom illumination interface S5 are located at the planes of the recesses defining the stand 1. A top lamp interface S8 and a bottom lamp interface S9 which are parallel to and at the same height as the top and bottom illumination interfaces S4, S5 are provided on the opposite outer side of the stand 1.

[0025] A complete illumination system for the transmitted illumination of the upright variant (Fig. 1a) is formed by arranging the lamp 5 at the bottom lamp interface S9 and the illumination module 3 at the bottom illumination interface S5. When arranging the lamp 5 at the top lamp interface S8 and the illumination module 3 at the top illumination interface S4, the optical paths between the illumination interfaces S4, S5 and the lamp interfaces S8, S9 are identical so that an optically identical illumination system results for the transmitted illumination of the inverted variant.

[0026] In order to form an illumination system for transmitted illumination, the lamp 5 is fastened to one of the lamp interfaces S8, S9 and the objective module 2 is fastened to the opposite illumination interface S5, S4, respectively. The interfaces are indicated in the drawings by dashed lines, each comprehending a physical edge. In reality, the interfaces have direct mechanical contact with one another and they coincide optically, i.e., they lie in a plane. Correspondingly, the same optical ratios apply to both. The interfaces mentioned above are located in an area of the imaging beam path or illumination beam path with a parallel beam course.

[0027] The illumination interfaces S4, S5 are brought together with an illumination-side illumination interface S6 for a vertical illumination system on the one hand and with an objective module-side illumination interface S7 for a transmitted illumination system on the other hand. In a corresponding manner, the vertical illumination system and the transmitted illumination system must be calculated in such a way that the optical ratios in the

illumination interface S6 on the microscope side are identical to the optical ratios in the illumination interface S7 on the objective module side.

[0028] The object stage carrier 4 is arranged at the stand 1 so as to be vertically displaceable, i.e., focusable, so as to displace the support plane of an object stage 8 fastened thereto in the object plane of the objective. The object stage 8 has an opening in the center for inserting different object holders or other inserts such as Petri dishes or microtiter plates so that it is suitable for vertical illumination and for transmitted illumination.

[0029] The objective module 2, which comprises, in addition to the objective, an incident light reflector with a beam-splitting deflecting element, communicates by its imaging interface S3 on the objective module side with the top imaging interface S1 for the upright variant and with the bottom imaging interface S2 for the inverted variant.

[0030] In a corresponding manner, the optical elements of the objective module 2 and of the tube 6 in connection with the optical elements in the top side (first optical path) of the stand 1 form the imaging system for the upright variant and in connection with the optical elements in the bottom side and the side connection (second optical path) form the imaging system for the inverted variant. In order to achieve the same imaging ratios for both variants, i.e., to offer identical imaging to the observer, the imaging interfaces S1, S2, S3 must lie in conjugate planes relative to one another when the two imaging systems are considered jointly. A deflecting element 7 is added to or removed from the beam path by means of an operator control located at the stand 1 so that the object imaging is carried out depending on the arrangement of the objective module 2 in the tube 6. In the inverted variant, the image transmission to the intermediate image of the eyepiece in the tube 6 is carried out by way of two image transmission systems (triplets) in which two intermediate image planes result in each instance in the coinciding image planes of the adjacent imaging elements. The second intermediate image plane in the imaging direction is the first intermediate image plane for the upright variant.

[0031] In the areas of the mechanical interfaces that are determined by outer contact surfaces of the components, the stand 1 comprises a metal-ceramic material, a metal alloy, or a composite material with high dimensional stability and excellent resistance to wear. The mechanical connection of the interfaces is advantageously implemented by means of slide guides so that the objective module 2 and the illumination module 3 can be fastened to the

stand 1 only in an angular position. The slide groove and slide spring forming a connection, respectively, are arranged at the stand 1 and at the objective module 2 and illumination module 3 in such a way that the offset of the optical axis is very slight. By means of a one-sided contact of the slide spring at the slide groove by means of screwing or clamping, the play in the slide guide is eliminated and a reproducible positioning of the objective module 2 and illumination module 3 at the stand 1 which does not permit the parts connected to one another to rotate is ensured. Tolerances with respect to positioning in the direction of the slide guide have no influence on the imaging quality. Accordingly, it is particularly advantageous that the interfaces are formed by slide guides. However, they can also be realized by means of other snap-in connections which are familiar to the person skilled in the art and which permit only one or two relative positions relative to one another.

[0032] A second embodiment example, shown in Figs. 2a and 2b, differs from the first embodiment example essentially in that the tube 6 is mounted on the stand 1 at the front rather than at the back from the point of view of the operator of the microscope. A construction of this kind is particularly advantageous when an invertible microscope is not required from the start, but rather when an upright microscope that can be converted in this sense is required. An inversion module containing the additional optical elements required for the inverted variant can be introduced, as needed, over the back wall or a side wall in the stand 1. The required optical elements can also be located at an interchangeable back wall.

[0033] In this embodiment example, the transmission optics for the inverted variant are 4f optics, as they are called, which are constructed as an afocal sequence of two relay optics and a tube lens. The intermediate image in the focal point M of the first relay optics J/K is received through the second relay optics N/O, imaged at infinity, and then imaged through the tube lens in the intermediate image plane of the eyepiece. The image-side focal point of the first relay optics coincides with the object-side focal point of the second relay optics. Also used are a penta prism I, two stationary deflecting elements L, P, and a deflecting element Q which is displaceable in the beam path by means of an operator control located at the stand 1. The displaceable deflecting element Q is needed for switching between the upright variant and inverted variant.

[0034] A third embodiment example shown in Figs. 3a and 3b differs from the second embodiment example through the transmission optics which are provided for the inverted

variant. For a favorable position of the intermediate image M, a glass block $W_1$ is used in this case following a stationary deflecting element $P_1$ and the tube lens $R_1$. This is followed by another stationary deflecting element L, a field lens $F_1$, an achromatic lens $V_1$, a penta prism $I_1$, and another achromatic lens $x_1$. A deflecting element $Q_1$ which is displaceable in the beam path is displaced together with the negative lens $N_1$ by an operator control located at the stand 1 in order to switch between the upright variant and the inverted variant.

[0035] The first three embodiment examples share the advantage that all components are always used for all variants. Only the objective module 2 and illumination module 3 need to be exchanged in order to convert from the upright variant to the inverted variant, and vice versa. The lamp 5 is mounted at one of two lamp interfaces S8, S9 to select between vertical illumination and transmitted illumination. It will be clear to the person skilled in the art that a variety of radiation sources commonly used in microscopy can be used as lamps 5.

[0036] The variable exchange of components is made possible in the three embodiment examples in particular in that the entire optical system is calculated in such a way that the pairs of interfaces – top and bottom imaging interfaces S1, S2, top and bottom illumination interfaces S4, S5, and top and bottom lamp interfaces S8, S9 – are provided at the stand 1 and the pairs of interfaces have optically identical ratios.

[0037] Further, the imaging interfaces S1, S2 and the illumination interfaces S4, S5 are adapted to one another optically in order to achieve sharp imaging and optimal illumination of the object plane in reflected light by means of the objective module 2.

[0038] Optics data which meet the required interface conditions were determined for an inverted variant of a microscope with transmitted illumination. These data are shown in Table 1. Uppercase letters were used in Table 1 and in Fig. 2b to associate the data with the individual optical components and indicated planes.

[0039] The fourth embodiment example, shown in Figs. 4a and 4b, differs essentially in that the imaging beam path is not guided through the stand 1. The stand 1 comprises a base plate 10 and a stand pillar 11 which is erected vertically on the latter. The base plate is advantageously U-shaped so that the required operator controls can be arranged at an ergonomically favorable height.

[0040] In this case also, the objective module 2 can be fastened to the stand 1 for the two microscope variants by means of a top and a bottom illumination interface S4, S5. As in the

embodiment examples described above, the lamp 5 can be positioned alternately at two locations at the stand 1; however, the lamp 5 in this fourth embodiment example serves only for vertical illumination. For transmitted illumination, a light source with a condenser lens which is arranged in the interior of the stand in the embodiment examples described above is to be arranged as a lamp assembly 5.1 in the base plate 10 or at a stand arm 9 so as to be in line with the objective. The illumination module 3 is arranged directly in front of the lamp assembly 5.1 for the inverted variant and is fastened to the object stage carrier 4 for the upright variant.

[0041] For the upright variant, the object imaging is carried out by means of the objective module 2 directly in the tube 6. For the inverted variant, an intermediate tube 12 is added between the objective module-side imaging interface S3 of the objective module 2 and the tube 6 which has a tube-side tube interface S10. In order to provide identical optical imaging ratios for the upright variant and inverted variant, the transmission optics in the intermediate tube 12 are calculated in such a way that they transmit the optical ratios in the imaging interface S3 on the objective module side into the tube interface S10 on the tube side in a ratio of 1:1.

[0042] A fifth embodiment example according to the invention is described with reference to Figs. 5a and 5b. In this case, the stand 1 is L-shaped. In the upright state of the stand 1 in the upright variant, shown in Fig. 5a, the base surface which is determined by the length and depth of the short side stands on a stand base 13. The objective module 2 is fixedly mounted to the overlap which is determined by the width and depth of the long side. In contrast to all of the embodiment examples described above, the microscope is converted from the upright variant to the inverted variant not by placing the objective module 2 at a different interface of the stand 1 but rather in that the stand 1 at which the objective module 2 is fixedly arranged is "stood on its head" so that the objective is located below or above the object stage 8.

[0043] For the upright variant, a trinocular tube that is formed by a tube 6 for visual observation and a camera tube 14 are attached to the imaging interface S3 on the objective module side.

[0044] For the inverted variant (Fig. 5b), an intermediate tube 12 which brings the eyepiece located at the tube 6 to an ergonomically favorable height for the user is arranged between the objective module 2 and the tube 6.

[0045] To provide identical optical imaging ratios for the upright variant and the inverted variant, the transmission optics in the intermediate tube 12 are calculated in such a way that they transform the optical ratios in the imaging interface S3 on the objective module side into the tube interface S10 on the tube side as takes place by means of the optical elements in the camera tube 14 which participate in the visually accessible imaging.

[0046] A lamp assembly 5.1 is connected directly to the objective module 2 for vertical illumination in the inverted variant. Together with the respective illumination module 3 which is arranged in front and is fastened to the object stage carrier 4, a second lamp assembly 5.1 which is accommodated in the short side of the stand 1 so as to be in line with the objective forms the illumination system for transmitted illumination.

[0047] The person skilled in the art of the field of the invention will appreciate that the invention is not limited to the details of the embodiment forms mentioned herein by way of example and that the present invention can be embodied in other specific forms without departing from the scope of the invention as set forth in the appended claims.

Reference Numbers

| | |
|---|---|
| 1 | stand |
| 2 | objective module |
| 3 | illumination module |
| 4 | object stage carrier |
| 5 | lamp |
| 5.1 | lamp assembly |
| 6 | tube |
| 7 | deflecting element |
| 8 | object stage |
| 9 | stand arm |
| 10 | base plate |
| 11 | stand pillar |
| 12 | intermediate tube |
| 13 | stand base |
| 14 | camera tube |

| | |
|---|---|
| S1 | top imaging interface |
| S2 | bottom imaging interface |
| S3 | imaging interface on the objective module side |
| S4 | top illumination interface |
| S5 | bottom illumination interface |
| S6 | illumination interface on the illumination side |
| S7 | illumination interface on the objective module side |
| S8 | top lamp interface |
| S9 | bottom lamp interface |
| S10 | tube-side tube interface |